

# Navigation Architecture for Future Mars Missions

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## **ABSTRACT**

### **Where Do We Go from Here?**

Reconnaissance and the search for water are central themes for Mars exploration during the first decade of the 21<sup>st</sup> century. Developing cost efficient individual flight projects that perform both orbital and surface exploration will likely require intelligent infrastructure elements for critical functions such as navigation.

Two orbiting spacecraft, Mars Global Surveyor (MGS) and the recent Mars Odyssey Orbiter (MOO) are in low, nearly polar orbits about the red planet. Future Mars arrivals will be able to use navigation and communications services of these orbiters. For example, the twin Mars Exploration Rover (MER) missions (early 2004 arrival) will be tracked by MGS during the Entry, Descent and Landing (EDL) phase, and then by MOO during surface operations.

Later, the planned 2005 Mars Reconnaissance Orbiter (MRO) will carry advanced radio and optical navigation capabilities to provide support for approach, EDL, surface and orbital rendezvous phases of missions launched during the 2007 opportunity. In turn, each of these 2007 missions (at least the ones with orbital assets) could carry the same navigation capabilities to reduce development and operations costs through reuse.

### **What's the Plan**

Figure 1. shows the planned missions out through 2009. Of course, Mars program trades continue and missions proposed beyond 2005 have not been approved at this time. Addressing navigation requirements of the many options beyond 2005 can be daunting given the inter-mission functionality and possible mission requirements.

Figure 2 shows the many possible navigation data types available for Mars cruise, approach, orbit and surface operations. The Earth-based measurements (DSN Doppler, range and  $\Delta$ VLBI) have been demonstrated and will remain integral for all mission phases. Optical navigation has been demonstrated and will be required for precision Mars approach targeting. Also useful for reducing approach navigation uncertainties is proximity radio navigation. This consists of collecting doppler measurements from surface or orbiting Mars assets. Figure 3 gives the relative performance of the various measurement types for a Mars approach.

Figure 4 is a cartoon representing options currently under evaluation. These primarily use proximity doppler measurements from a relay orbiter for surface positioning and orbit

determination. Mars orbital rendezvous may use optical sensors on a relay orbiter to assist with initial search operations.

### **Conclusions**

Future Mars missions will benefit from the currently established and proposed navigation infrastructure elements. Mars flight projects that take advantage of enhanced options such as proximity navigation can reduce dependence on Earth-based tracking resources while enabling more accurate position and velocity determination.

### **Acknowledgements**

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2001



Mars Odyssey

2003



Mars  
Exploration  
Rovers

2005



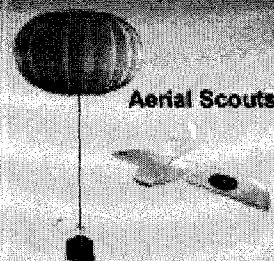
Mars Reconnaissance  
Orbiter

2007



ASI Telecom

CNES Aerocapture



Aerial Scouts

Netlanders



Smart Lander  
& Rover

2009

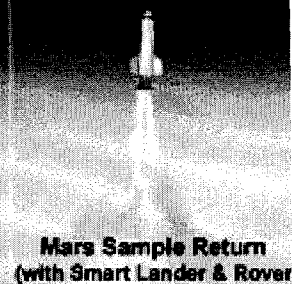


ASI/U.S. SAR

2011

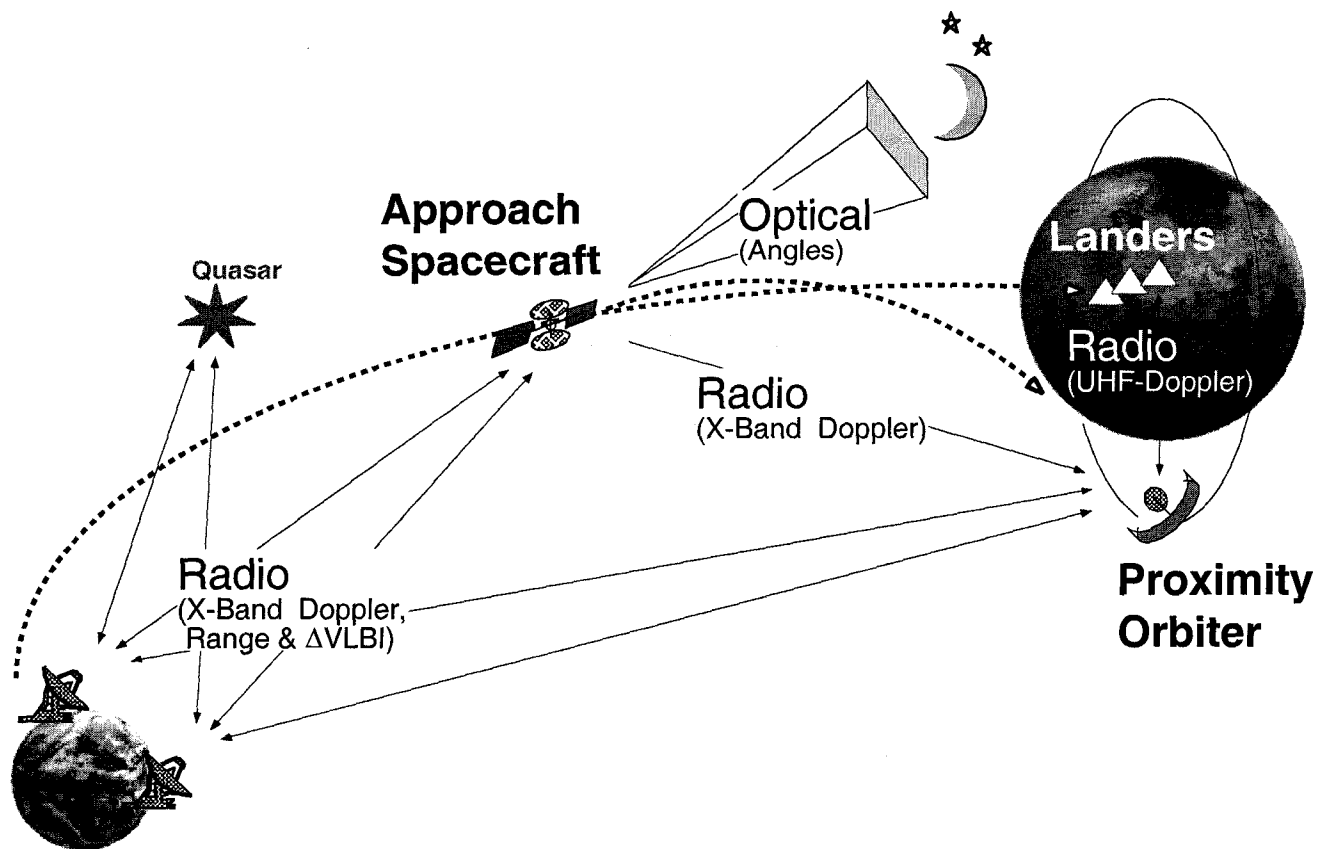


CNES Return

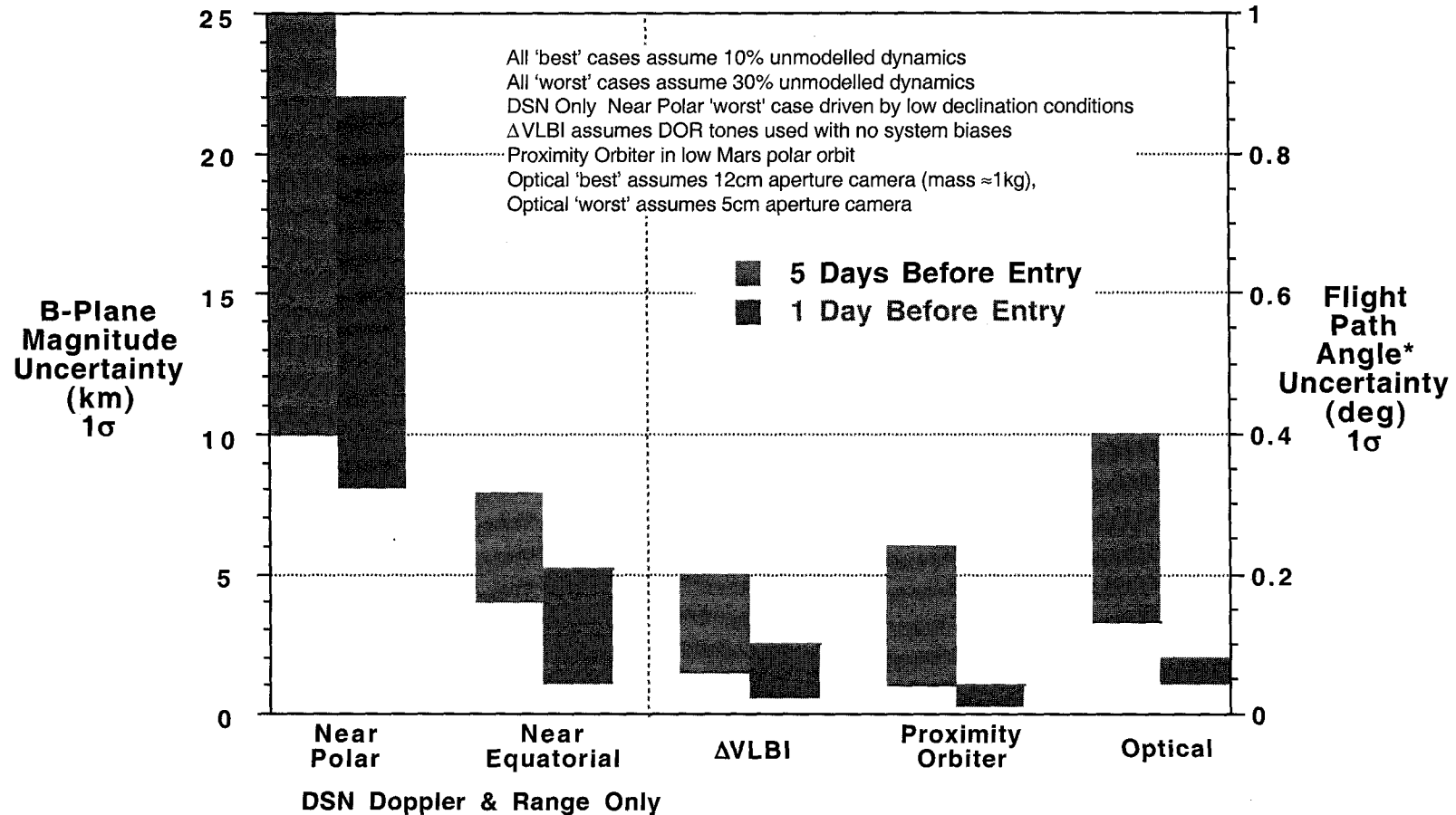


Mars Sample Return  
(with Smart Lander & Rover)

Fig. 2  
**Mars Navigation Observations**



**Fig. 3**  
**Mars Lander Approach Navigation**  
**Atmospheric Entry Performance**



Mapping between Flight Path Angle and B-Plane Magnitude Uncertainties depends on entry conditions.  
 All cases assume equivalent mapping for -15 deg Flight Path Angle and -5345km B-Plane Magnitude

**Fig. 4 – Proposed Mars Navigation Architecture (200?)**

